4.0 ECONOMICS

A number of economic and cost-benefit life cycle analyses of bioreactor landfills are being conducted by EPA and private industry. These are presented in Sections 4.1 and 4.2, respectively. Section 4.3 summarizes economic considerations identified in the course of Workshop discussions.

4.1 ECONOMIC ANALYSES CONDUCTED BY EPA OSW

EPA OSW has been evaluating the costs and benefits of bioreactor landfills. The basis of this analysis involves the volumes and estimated components of municipal solid waste. In 1998, there were about 158 million tons of municipal solid waste and construction and demolition (C&D) debris waste placed in municipal solid waste landfills. Over half of this waste (84 million tons) was organic with the following estimated composition:

- Paper – 37.8%
- Food – 16.6%
- Yard trimmings – 11.7%
- Wood – 8.6%.

This analysis did not consider plastics and textiles in the waste volume as was noted in the Section 3.1 waste composition discussions. Approximately 83 percent of the organic waste is estimated to be amenable to decomposition.

Also of note for this economic analysis is that 84 million tons of municipal solid waste generate 6 million tons of methane and take up 85 million cubic yards of landfill space.

In evaluating the economics of bioreactor landfills, EPA OSW is examining the following concerns:

- Do bioreactor landfills pose a disincentive to recycling, reuse, and other options for waste material that may be used in the bioreaction process (i.e., will bioreactors preferentially increase the waste volume that is land disposed)?

- Are there other viable alternatives to manage organic wastestreams, such as composting, so that these wastes can be diverted from land disposal and stabilized in a much smaller amount of time than would occur in a bioreactor?

Section 4.1.1 provides an overview of this economic analysis. Section 4.1.2 presents the preliminary findings.

4.1.1 Economic Study Overview

Data needs for this and other related economic analyses include the following:

- Costs of bioreactor landfill design, construction, and operation

- Cost data to compare the effectiveness of bioreactor landfills against composting of organic materials and against conventional landfills for inorganic materials.

For purposes of this Workshop, presentations of this economic analysis focused on the comparison of bioreactor landfills with composting of organic matter.

This EPA study considers the following additional costs realized by bioreactor landfills over conventional municipal solid waste landfills:

- Construction costs associated with the installation of enhanced leachate recirculation devices and landfill gas collection systems

- Operating costs resulting from increased leachate recirculation, gas generation, permitting fees, and equipment/manpower needs.

Note that the cost per ton estimates used in this economic analysis represent the cost to the local municipality and assume separate collection of materials diverted for composting or other action. These costs were derived from an EPA guidebook published several years ago with estimates of the cost per ton to institute grass recycling and similar programs.

Potential benefits of bioreactor landfills being considered in this economic analysis include the following:

- Reduced leachate treatment/disposal costs
- Saved landfill space
- Extended landfill life
- Deferral of new cell construction
- Post-closure savings from fewer monitoring and financial assurance requirements
- More efficient gas collection with potential for revenues from energy production.

Final cost-benefit criteria for this analysis currently focus on:

- Avoided methane emissions, including revenues from energy production and greenhouse gas credits for avoided emissions

- Landfill space saved, such as additional capacity and quantities of organics diverted from landfills

- Changes in waste management costs, such as comparisons of additional operating costs against savings and incremental costs of diversion against disposal.

Uncertainties affecting the economic analysis include the following:

- How does leachate recirculation affect waste densities, settling, and compaction?

- How much more capacity is actually obtained with bioreactors vs. traditional landfills and what is the value of the "saved" space?

- How much additional methane is generated and how much can reasonably be captured?

4.1.2 Preliminary Results

Preliminary results of EPA's economic research and analysis for the comparison of bioreactor landfills and organic composting indicate that:

- Bioreactor landfills may offer improved performance and cost savings over conventional landfills

- Organic diversion has the potential to save significantly more landfill space than bioreactor landfills

- Improved diversion of organic material could more significantly reduce waste management costs than the use of bioreactor landfills

- 25.6 million cubic yards of landfill space may be saved based on an assumption that 13% additional capacity is generated by bioreactor landfill operations and consideration of different density factors for different wastes in the landfill

- Avoided methane and other gas emissions (through energy recovery or other gas collection/utilization projects) have the potential to be considered "avoided greenhouse gas emissions" for purposes of economic analyses

- Savings from bioreactor methane are longer-term than those achieved by organics diversion, which tend to be short-term based on greenhouse gas emission credits.

This economic analysis does not currently address gases other than methane (such as CO_2). EPA also anticipates looking at the economics of transportation and other factors in combination with the end results of waste management.

4.2 Modeled Economics of Landfill Bioreactors by Private Industry

Waste Management Incorporated (WMI) is working on a variety of bioreactors and is investigating the life cycle economics of these landfills as compared to more conventional municipal solid waste landfills. WMI is developing a cost model that draws on theoretical data obtained in the United States and Europe to assess the financial investment and returns on investment for various types of landfills to identify the most cost-effective approaches, and to identify the factors that drive the economics of bioreactor landfill implementation and operation.

The economic analysis considers two broad categories: new construction of bioreactor landfills and retrofit of existing landfills to become bioreactors. The analysis also considers 10 landfill types:

- Aerobic, retrofit landfill
- Anaerobic, retrofit landfill
- Facultative, retrofit landfill
- Hybrid aerobic/anaerobic retrofit
- Aerobic, new construction landfill
- Anaerobic, new construction landfill
- Facultative, new construction landfill
- Hybrid aerobic/anaerobic, new construction landfill
- Base case, conventional municipal solid waste landfill.

The economic model considers all construction costs as well as those associated with operations, capping, closing, etc. to determine the investment required. The model also considers all investments necessary such as legal, permitting, and other cost factors.

The following sections provide an overview of the economic model and the initial results of the economic analysis. Section 4.2.1 summarizes general background information on assumptions used in the economic model. Section 4.2.2 presents preliminary findings and conclusions regarding bioreactor landfill functions, cost drivers, and overall economics.

4.2.1 Economic Model Assumptions

The different landfill types were compared to a "base" landfill with the following features:

- 140 acres with 10-acre cells and 800 cubic yards of waste in place
- Operates 275 days per year
- 2,500 tons per day of municipal, construction and demolition (C&D), solidification, and special wastes.

New landfills were similar to the "base" landfill in these features. However, the retrofit landfills involved 30-acre plots.

The economic model considers the use of other clear liquid waste streams in addition to leachate. These included clear aqueous waste streams from lettuce processing, soft drink manufacturing washdown, bakeries, etc., that had high BOD and low solids. Biosolids that could be added in liquid form were also considered and are of particular interest because they are readily available and may be relatively economical to use depending on fees and taxes.

Uncertainty presently exists regarding how leachate and other liquids will be added to the landfill waste mass. For example, there are days when workers may not be on site to conduct liquid addition (e.g., Sundays), and there are also considerations of whether to add liquids on days when it rains or snows.

Assumptions used for gas generation and management in the economic model include the following:

- Aerobic reactors have no recoverable methane (although actual experience is that there are some methane emissions
- Facultative bioreactors will produce methane at 1.5 times the rate of Subtitle D landfills
- Anaerobic and hybrid bioreactors produce methane at 2 times the rate of Subtitle D landfills and produce it very quickly.

Also, in its current form, the economic model does not assume any differences in post-closure care between the nine types of landfills.

4.2.2 Preliminary Findings

Data from the economic analyses have been compiled into tabular form to facilitate comparison of the different landfill scenarios considered in the analysis. Comparisons of all landfill scenarios to the base case determined the following for bioreactor operations:

- Gain in landfill space of 15 to 30 percent.

- Increased density of waste mass.

- Increased landfill life.

- Reduced regulatory and permitting costs over "base" landfill case.

- Significant revenues from gas generation.

- A gas collection system is more expensive to retrofit into an existing landfill (this model assumed no gas collection system for an aerobic landfill).

- Odor control systems that counteract the odor rather than mask it may be necessary. Such systems are not expensive to install, but are expensive to operate and can drive the economic model.

- Some substantial increases in investment with some offsets. For example, new construction costs may be more advantageous than retrofitting.

- Ammonia removal may also be necessary.

The largest changes in estimated costs for various types of bioreactors were found for the following factors:

- Aeration of mass or leachate
- In-situ performance monitoring instrumentation (temperature)
- Reduced leachate disposal
- Health and safety (if liquid used rather than caked biosolids)
- Odor control (significant cost per day)
- Dozer operation
- Increased water truck usage
- Decreased new construction.

WMI examined the factors that drive this economic model based on experience gained at its Metro and Live Oak facilities. These factors include, but are not limited to, the following:

- 15% gain in airspace for retrofit with 30% gain in new landfills

- Increased manpower for gas technicians (retrofit)

- Increased manpower for daily operations (e.g., new landfill requires an additional dozer operator and additional technicians to place pipe/monitor).

Potential bioreactor landfill benefits identified from these analyses include the following:

- Reduced post-closure period

- Reduced heavy equipment usage because there is less need for waste compaction

- Decreased air emissions

- Reuse of old landfill airspace on a full-scale basis — a very critical factor from the perspective of private industry.

Potential risks associated with bioreactor landfills include the following:

- Changes in design and construction to make wider cells allowing for flatter filling lifts, which involve stability and safety issues

- Changes in slope construction from 3:1 to as much as 4:1, which would result in a net loss of airspace and may preclude future reuse of the air space for waste addition

- Personnel hazards from more operating equipment, which increases the opportunity for accidents

- Odor problems.

The following conclusions were offered regarding the results of the economic analyses:

- Airspace recovery drives the economic model because that is the key selling factor to those who run landfills.

- Addition of biosolids may be an important factor and may be especially important to new construction bioreactors.
- Bioreactors do not appear to be viable in dry areas without large water sources.

- Installation of a gas collection system is less expensive for bioreactor landfills if done at the time waste is first placed in a new landfill. Even delays of only 2 years can render this economically nonviable.

- Much of the early work on bioreactors involves retrofit of existing landfills because this is easier than building a new landfill. Efficiencies and ease of applying these techniques to new landfill cells may be significantly more beneficial than retrofitting.

- Retrofitted landfills are easier to operate because of the lack of traffic for new waste and the absence of interferences from the work force that may be encountered at an active landfill.

- Aerobic landfills need to be better defined. Experience to date suggests that retrofit aerobic bioreactors are really anoxic and do not actually have aerobic kinetics.

Based on recovered air space alone, bioreactors appear to make economic sense. However, retrofitting existing landfills for bioreactor operations may not be economically viable. Additional research is needed to determine if this economic model is correct, since many of the assumptions are not yet proven at large scale.

4.3 Decision Support Tools for Estimating Landfill Gas Emissions

There are existing tools that may either be directly applicable or potentially modified to predict landfill gas emissions associated with the operation of landfills as a bioreactor. A tool that has been used to calculate the tradeoffs in environmental burdens is the municipal solid waste decision support tool (MSW-DST). This tool was developed through a cooperative agreement (CR823052) between EPA and the Research Triangle Institute. The methodology incorporates a life-cycle evaluation of the full range of multi-media and multi pollutant tradeoffs in addition to providing the full costs of a solid waste system. All the waste management activities are modeled including collection, transportation, recycling/composting, and treatment (e.g., landfilling and combustion). For those materials that are potentially recoverable and displace virgin resources and/or conserve fossil fuels, offsets are calculated for each of the recoverable materials in municipal solid waste (e.g., aluminum cans, steel cans, corrugated containers, newsprint). This tool took over 6 years to develop and has undergone rigorous stakeholder and program peer review from international experts. The result is a credible, state of the art tool for evaluating different strategies for integrated waste management.

One of the options as part of the landfill process model is operating the landfill as a bioreactor. The defaults are based on expert opinion but there is no long term data to confirm if these are accurate. Data resulting from ongoing field studies will help to determine if these defaults need to be modified.

For more information regarding the MSW-DST, refer to the project website at: www.rti.org/units/ese/p2/lca.cfm#life. This website provides a brochure and a PowerPoint™ presentation of the decision support tool, and will be updated to provide additional outputs and information on the availability of the decision support tool and life-cycle inventory database. The research team is also preparing a series of peer-reviewed journal articles to highlight the different aspects and uses of this tool and to summarize findings from case studies in different communities where this life-cycle tool has been applied.

EPA is seeking the following information to help more reliably quantify the potential burdens and/or benefits associated with bioreactors:

- Long-term bioreactor landfill operating data from operating facilities and/or demonstration projects
- Long-term data to develop or validate model inputs for anaerobic, aerobic or hybrid bioreactors
- Data to evaluate different options in use for landfill gas collection and control including timing of installation, length of time in place, type of material for cover to minimize fugitive emissions, etc.
- Types of operating data needed to support permitting and/or enforcement.

The EPA also has available a tool (i.e., Landfill Gas Emission Model[1], or LandGEM) that is used to develop state and national emission inventories, and determine applicability to CAA regulations. The model is based on a first-order decomposition rate equation. However it is based on conventional landfilling practices and would need modification to reflect bioreactor operations.

In addition to the above needs, data are also needed on:

- The potential for fugitive landfill gas emissions as compared to conventional landfilling practice
- Efficiency of existing methods for detecting landfill gas fires and/or landfill gas collection/control failures

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[1] (Thornloe, S.A., A. Reisdorph, M. Laur, R. Pelt, R.L. Bass, and C. Burklin, The U.S. Environmental Protection Agency's Landfill Gas Emissions Model (LandGEM), Sardinia '99, *Seventh International Waste Management and Landfill Symposium*, Published in Proceedings, Volume IV, Pages 11-18, October 4-8,1999.)

- Information regarding contingency plans for landfill fires.

4.4 Economic Aspects Identified by Workshop Participants

Throughout Workshop discussions, participants provided a number of suggestions regarding factors to consider in economic and cost-benefit evaluations of bioreactor landfills. Many of these suggestions are presented throughout other sections of this document in the context of those particular discussions. To briefly summarize, economic and cost-benefit considerations include, but are not limited to, the following:

- Leachate transport, treatment, and disposal costs will be reduced by recirculation of this waste stream in the landfill. Off-setting costs include those associated with leachate recirculation system installation and operation.

- Increased disposal revenues from use of additional landfill capacity realized from the rapid settlement of the waste mass seen in bioreactor operations. During the landfill operational period, this allows placement of more waste tonnage into the same amount of permitted landfill volume.

- Significant increases in landfill operating life realized from the rapid settlement of the waste mass seen in bioreactor operations.

- Potential for gas recovery projects to use the large quantities of methane generated by bioreactor landfills. Economics may vary based on landfill size (smaller may be disadvantageous) and whether greenhouse gas credits can be sold. Cost off-sets also exist for installation and operation of the gas collection and management system as well as investments associated with waste preprocessing (e.g., shredding) that may be necessary for optimum gas generation.

- No energy project potential exists for aerobic bioreactors because they do not produce such significant quantities of methane as are found in anaerobic bioreactors.

- Decreased municipality cost to treat and land apply biosolids from POTWs that are instead used for liquid addition in bioreactor landfills. Off-setting costs include increased transport requirements to move a larger waste volume of liquid waste to the landfill.

- Revenues from recovery and reuse of the humus-like substance resulting from bioreaction.

Workshop participants all agreed that any economic or financial analysis must address specific goals to be achieved. These may be airspace recovery, leachate management cost reduction, methane gas recovery, or others. Thus, the outcome of the economic or financial analyses will vary and may be difficult to compare because the financial benefit depends on the goals.